Pedobiologia **29**, 327—339 (1986)
VEB Gustav Fischer Verlag Jena

Department of Soil Science, University of Alberta, Canada, USA

The development of soil structure by *Octolasion tyrtaeum*, *Aporrectodea turgida* and *Lumbricus terrestris* in parent materials belonging to different textural classes

C. Shaw[1]) and S. Pawluk

With 7 figures

Accepted: 85-11-01)

1. Introduction

It has been accepted for some time that earthworms play a unique role in the development of soil structure. Despite this fact many gaps in our knowledge and conflicts of opinion regarding the nature of this relationship still exist.

It has frequently been stated that earthworms produce a favourable, granular, mull type of soil structure (Babel 1975, Kühnelt 1958). This conclusion has often been based on the observed association between the presence of earthworms and granular soil structure although no cause-effect relationship has been established (Nielson & Hole 1967, Buntley & Papendick 1960, Langmaid 1964). In the parkland and prairie regions of Canada it has been reported that introduced earthworms ruined the granular, friable structure of Chernozemic clay soils by turning it into a sticky, unmanageable mass (Thorp 1949).

Earthworms can be classified into ecological groups which are defined by feeding behavior and spatial distribution in the soil (Perel 1977). The effect earthworms have on soil processes reflect how they function ecologically, yet little work has been done to demonstrate these differences in terms of soil structure development.

This study was designed to determine if earthworms acting alone can produce a granular, mull type of structure and if so; does this depend on the original texture of the soil and/or the species of earthworm involved? Since few efforts have been made to relate the development of soil structure by earthworms to the potential mechanisms for stabilization, analyses were carried out to investigate the possibility that earthworms enhance the concentration of uronic acids and/or neutral sugars and their binding with clays in the soil.

2. Material and methods

Three calcareous parent materials exhibiting a different particle size distribution (Table 1) were selected for this study. These parent materials are relatively devoid of structural development and chemical characteristics known to adversely affect the activity of earthworms. Undisturbed cores and bulk samples were collected in the field. The latter were air dried in the laboratory and ground to pass a 2 mm sieve.

Table 1. Particle size distribution for three parent materials

Textural designation	% Sand	% Silt	% Clay
Sandy Loam (SL)	84.4 ± 0.3	6.1 ± 1.2	9.5 ± 1.5
Clay Loam (CL)	35.1 ± 0.1	29.5 ± 0.1	35.3 ± 0.3
Silty Clay Loam (SiCL)	8.6 ± 0.1	58.4 ± 0.6	33.0 ± 0.4

[1]) Corresponding author.

Earthworm species were chosen to represent two ecological groups (PHILLIPSON *et al.* 1976). *Lumbricus terrestris* (LINNAEUS) was selected from the anecique group while *Octolasion tyrtaeum* (SAVIGNY) and *Aporrectodea turgida* (EISEN) represented the endogie group. A subsample of specimens from the collection site were sent to Dr. V. MARSHALL at the Pacific Forest Research Centre in Victoria, B.C. for identification.

Each unit in the experiment consisted of a plexiglass column. Bulk soil was packed into each column and space was left at the top for the addition of the undisturbed core. All columns were wetted from below and allowed to drain freely. Subsequent additions were made to produce the following treatments in triplicate for each soil texture.

Treatment 1: Soil + grass (*Poa pratensis* L./*Festuca rubra* L.)
Treatment 2: Soil + grass + *O. tyrtaeum*/*A. turgida*
Treatment 3: Soil + grass + *L. terrestris*
Treatment 4: Treatment 2 + *L. terrestris*
Treatment 5: Soil alone

The number of earthworm specimens added to each treatment was extrapolated from field population densities reported in the literature. Five specimens with a mean mass of 0.8 g from the endogie group were added to columns in Treatments 2 and 4 and 2 specimens of *L. terrestris* with a mean mass of 2.0 g were added to Treatments 3 and 4. The columns were maintained under controlled environmental conditions (10 °C and 14: 10 h day/night cycle through controlled lighting) and additions of 0.5 g of grass (*Poa pratensis* L./*Festuca rubra* L.) (O.D.) were made on a monthly basis where required.

At the end of a year, one replicate from each treatment was used to prepare a 32 μm thick section according to procedures previously outlined (BREWER & PAWLUK 1975). Thin sections were described using the terminology of BREWER (1976) and BREWER & PAWLUK (1975). The remaining two replicates from each treatment were dissected into parts (unaltered soil, tunnel linings, faecal pellets) for chemical analyses. The samples were air dried and ground to pass a 2 mm sieve.

The stepwise extraction procedure described by ANDERSON *et al.* (1974) was modified for the analysis of uronic acids and neutral sugars. The NaOH-$Na_4P_2O_7$ extraction was replaced by a 0.5 N NaOH extraction since the pyrophosphate interfered with the colorimetric determination of the neutral sugars. Acidification to separate the humic acid/fulvic acid components was not carried out since concentrations of uronic acids and neutral sugars were so low that such a separation made their detection impossible. Thus, the following three components were extracted:

(1) Free or weakly organically bound component (0.5 NaOH);
(2) Clay-bound component (after sonification);
(3) Residual component (humin).

Once obtained the extracts were hydrolyzed in 3 N H_2SO_4 at 121 °C and 103.4124 kPa [$\triangleq$ 15 psi][1]) for 1 h (DORMAAR *et al.* 1962). Aliquots of the hydrolyzates were eluted through Amberlite IR-120 cation exchange resin to remove interfering cations (DOUTRE *et al.* 1978). Amberlite IRA-400 anion exchange resin (acetate form) was used to separate uronic acids from neutral sugars (GREENLAND *et al.* 1975, THOMAS & LYNCH 1961). Neutral sugars were determined using the phenol sulphuric acid method (DUBOIS *et al.* 1956) and D-galactose as a synthetic standard. Uronic acids were determined using carbazole (BITTER & MUIR 1962) and galacturonic acid monohydrate as a synthetic standard (MCGRATH 1971).

Data were analyzed using two different analysis of variance models depending on the type of data under consideration. Unaltered soil data were analyzed as a 3×5 factorial experiment. Data for parts dissected from the columns were analyzed using a split-plot design where the whole plot was a 3^2 factorial with soil type and treatment at 3 levels and the dissected part was the split-plot factor. Where significant F tests occurred (F-ratio $> 5\%$ probability level) means were compared by the Student-Neuman-Keuls procedure at the 0.05 significance level.

X-ray diffraction analyses were performed on the $< 2\,\mu$m fraction from the faecal pellets of *O. tyrtaeum*/*A. turgida* and *L. terrestris* and control soil samples. Six pretreatments included Ca-saturated at 54% R.H. and ethylene glycol solvated and K-saturated at 105 °C (0% R.H.), 54% R.H., 300 °C and 550 °C. The analysis was repeated on the same samples after treatment with H_2O_2 to remove organic matter.

3. Results

3.1. Soil fabrics (see Table 2 for descriptive terminology)

The addition of grass alone (Treatment 1) to the soil columns did not result in any profound changes to the soil fabrics relative to the controls (Treatment 5). Thus, changes to the fabric of soils where both grass and earthworms were added may be safely attributed to the activities of the latter. Fabrics of the controls from the SL, CL and SiCL soils are dominantly matrichlamydic (Fig. 1a, 4a), metafragmoidic (Fig. 2a) and vughy porphyric (Fig. 3a), respectively.

[1]) 1 psi = 1 lbf/sq in = $6.89476 \cdot 10^3$ Pa = 6.89476 kPa.

Table 2. Guide to fabric descriptions

Related distribution of matrix and framework members:[1])	
orthogranic	— loosely packed mineral grains or discrete units (no coatings);
matrichlamydic	— mineral grains coated with matrix material (e.g., clays, organics);
matriplectic	— mineral grains coated with matrix material so that bridges form between the grains;
porphyric	— a dense groundmass of matrix material and mineral grains;
metafragmoidic	— units of densely packed matrix material which are fused and at least partially accommodated and have smoothed edges (i.e., partially separated by planar voids);
vughy porphyric	— a kind of porphyric fabric including many smooth edged voids;
matrifragmoidic	— like metafragmoidic but units lack smoothed edges;
mullgranic	— unaccommodated, loosely packed, discrete units of plasma and skeletal grains with plasma birefringence masked by organic matter;
phyto-	— plant fragments;
aggrotubules	— soil which is distinguishable from the associated material due to its tubular external form;
metavughs	— irregular, large voids with smoothed walls.

(—) intermixed fabrics, (/) fabrics in distinct zones, (//) zones grade into one another. The last fabric described (far right) is dominant. Where there is no hyphen or slash fabrics represent intergrades where no one type dominates.

[1]) For detailed descriptions see BREWER (1976).

Where *O. tyrtaeum*/*A. turgida* were active alone (Treatment 2) changes to soil fabrics are similar across all three soil textures (Figs. 1b, 2b, 3b). These soils are characterized by the presence of two distinct zones in which phytogranic units are absent. Zone I occurs at the soil surface and is dominated by porphyric fabric types. Zone I of the SL soil has a matriplectic porphyric fabric (Fig. 4b) and no faecal pellets or aggrotubules occur as discrete unit. Fabrics of Zone I in both the SiCL and CL soils have a minor metafragmoidic component (Figs. 2b, 3b). A small area of matrigranic fabric occurs in the CL soil (Fig. 2b). The matrix material of Zone I in all the soils is browner in color than the underlying material in Zone II due to the presence of humified plasma (colloidal organic matter) concentrations (Fig. 4b). The dominant fabric type in Zone II is similar to that of the corresponding control, except that it contains inclusions of the fabric type found in Zone I. Aggrotubules and metavughs occur as pedological features and zones of compaction occur in association with some of them. Changes to plasmic fabrics (distribution and orientation of clay domains) are most significant in the CL soil. Skel-vo-ma-mosepic fabric (Fig. 5a) dominates the control while a skel-in-masepic (Fig. 5b) fabric dominates both Zones of Treatment 2. Areas of strongly oriented clay commonly occur throughout the matrix material and around channels and smooth metavughs. Some areas of bimasepic plasma fabric (striated plasma elongated in two directions perpendicular to one another) are present in Zone I, but not Zone II or the control, of the SiCL soil.

Soil fabrics resulting from the activities of *L. terrestris* (Treatment 3) can be divided into two zones as with the endogeous species. Zone I occurs in association with a singular, large, vertical channel and at the soil surface (Figs. 1c, 2c, 3c). Thefabric is dominantly porphyric and the matrix is higher in humic material than Zone I of Treatment 2. Phytogranic units are admixed in the matrix material and occur in association with faecal pellets deposited on the soil surface. In the SL soil few faecal deposits occur as discrete units (Fig. 1c). Where a significant proportion of clay is present in the soil (SiCL, CL), faecal material is deposited on the soil surface extending the length of the main channel (middens) (Figs. 2c, 3c). In the SiCL soil some surficially deposited faecal material occurs as discrete granic units (Fig. 3c) while in the CL soil the faecal material is fused (Fig. 2c). Unistrial (Fig. 5b) and

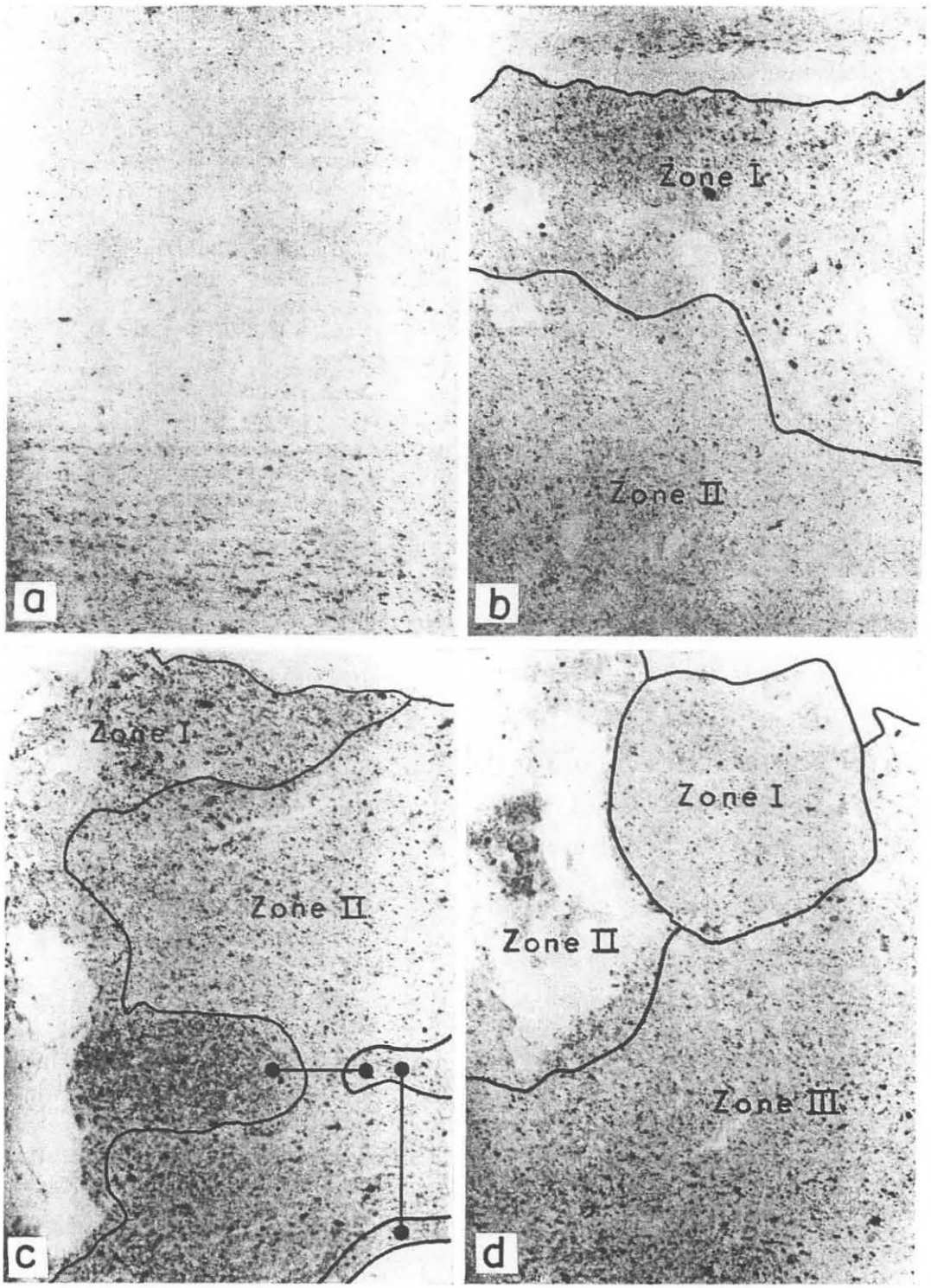

Fig. 1. Soil fabrics of the control and produced by earthworms in the Sandy Loam (SL) soil. Plain light. Frame width 15 mm. **1a.** Control; orthogranic-matrichlamydic. **1b.** *O. tyrtaeum/A. turgida:* Zone I: matriplectic porphyric, Zone II: matriplectic. **1c.** *L. terrestris;* Zone I: matriplectic/matriplectic porphyric, Zone II: matriplectic matrichlamydic. **1d.** *O. tyrtaeum/A. turgida/L. terrestris:* Zone I: metafragmoidic matriplectic matrichlamydic, Zone II: porphyric/matriplectic, Zone III: porphyric/matriplectic/matrichlamydic.

omnisepic (whole field of view shows striated plasma separations) plasma fabrics dominate the faecal material of the CL and SiCL soil respectively. Zone II occurs in all regions outside Zone I and is typically separated from Zone I by a planar void. The fabrics are similar to those of the corresponding controls with very minor inclusions of smoothed metavughs and faecal pellets.

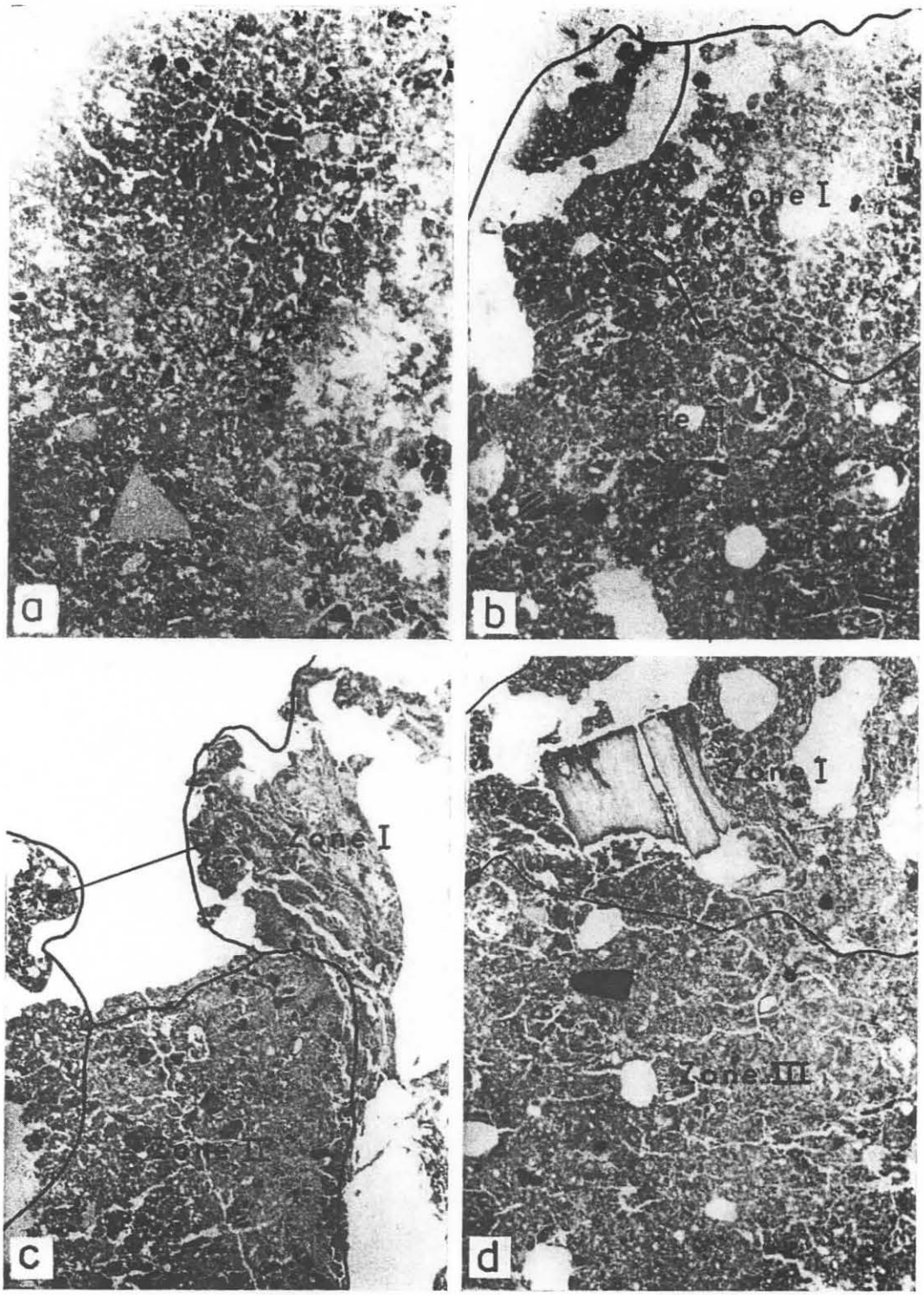

Fig. 2. Soil fabrics of the control and produced by earthworms in the Clay Loam (CL) soil. Plain light. Frame width 15 mm. **2a.** Control; metafragmoidic/metafragmoidic vughy porphyric. **2b.** *O. tyrtaeum/A. turgida;* Zone I: metafragmoidic, Zone II: metafragmoidic porphyric. **2c.** *L. terrestris;* Zone I: Porphyric, Zone II: metafragmoidic/vughy porphyric. **2d.** *O. tyrtaeum/A. turgida/L. terrestris;* Zone I: porphyric, Zone III: matrifragmoidic porphyric/vughy porphyric.

Where both ecological groups of earthworms co-existed (Treatment 4) soil texture controlled the type of fabric observed to the greatest extent (Figs. 1d, 2d, 3d). Distinct zones exist in these soils as in those from other treatments. Zone I occurs at the surface in all soils and is characterized by the presence of many individual and/or fused faecal pellets. Middens observed in soils where *L. terrestris* was active alone, are not present. The matrix

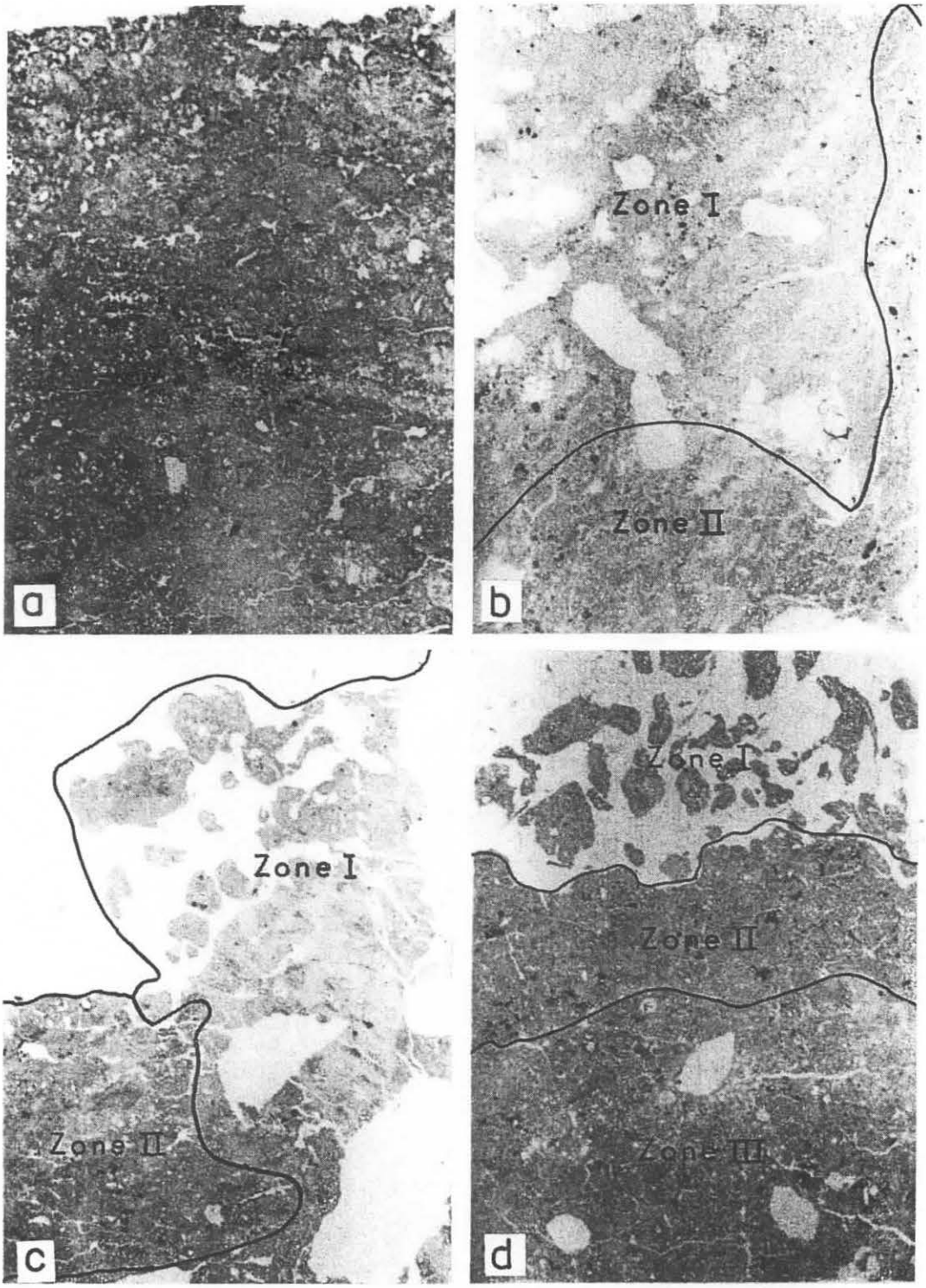

Fig. 3. Soil fabrics of the control and produced by earthworms in the Silty Clay Loam (SiCL) soil. Plain light. Frame width 15 mm. **3a.** Control. Vughy porphyric. **3b.** *O. tyrtaeum*/*A. turgida*; Zone I: metafragmoidic porphyric, Zone II: vughy porphyric. **3c.** *L. terrestris*; Zone I: porphyric, Zone II: vughy porphyric. **3d.** *O. tyrtaeum*/*A. turgida*/*L. terrestris*; Zone I: phyto-mullgranic, Zone II: metafragmoidic porphyric, Zone III: porphyric.

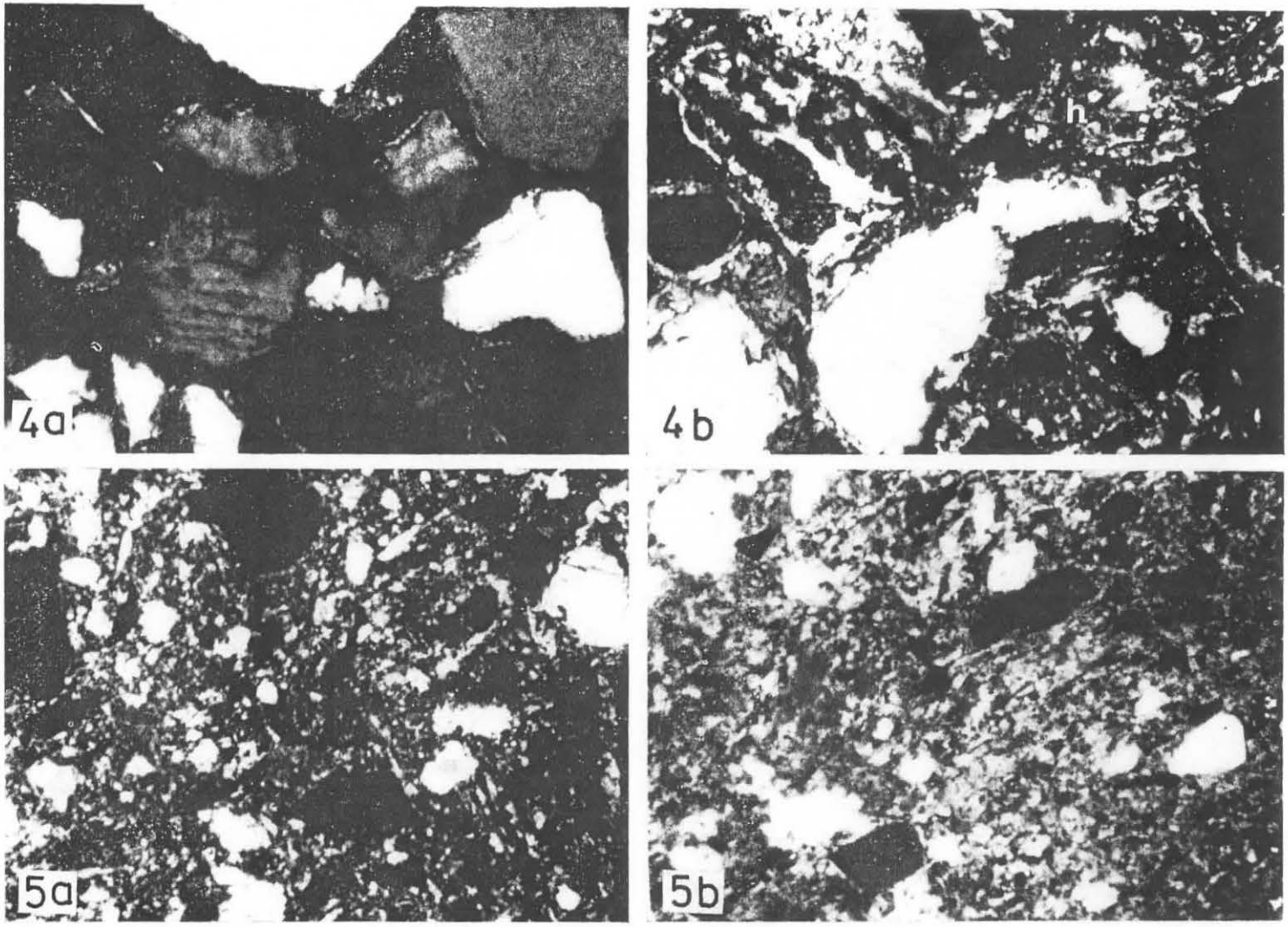

Fig. 4. Plasma fabrics of the control **(4a)** and Zone I produced by *O. tyrtaeum/O. tyrtaeum* **(4b)** in the SL soil. Crossed polarizer (80 ×), (h) — humified plasma concentrations.

Fig. 5. Plasma fabrics of the control **(5a)** and from Zone I produced by *O. tyrtaeum/O. tyrtaeum* and *L. terrestris* **(5b)** in the CL soil. Crossed polarizers (80×). **5a.** Skel-vo-ma-mosepic. Clay domains occur dominantly in a flecked pattern while some occur as separations along skeletal grains and voids. **5b.** (unistrial) in-masepic. Masepic fabric is one where clay domains occur in elongated zones. Unistrial is an extreme expression of a masepic fabric.

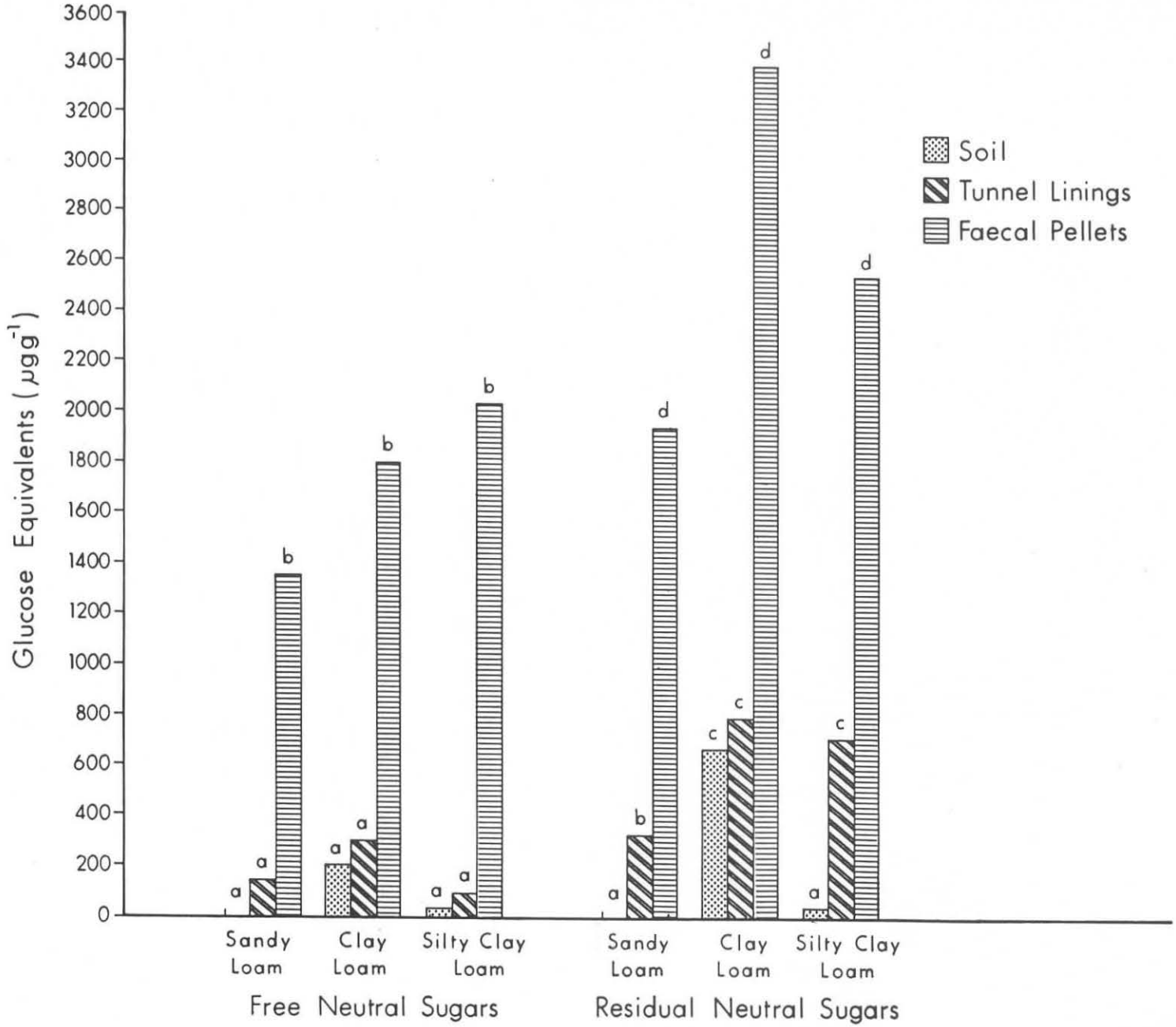

Fig. 6. Distribution of free and residual neutral sugars (μg glucose eq g^{-1} soil) between soil textures and parts (a—d significantly different, within type of extract, $P \leq 0.05$).

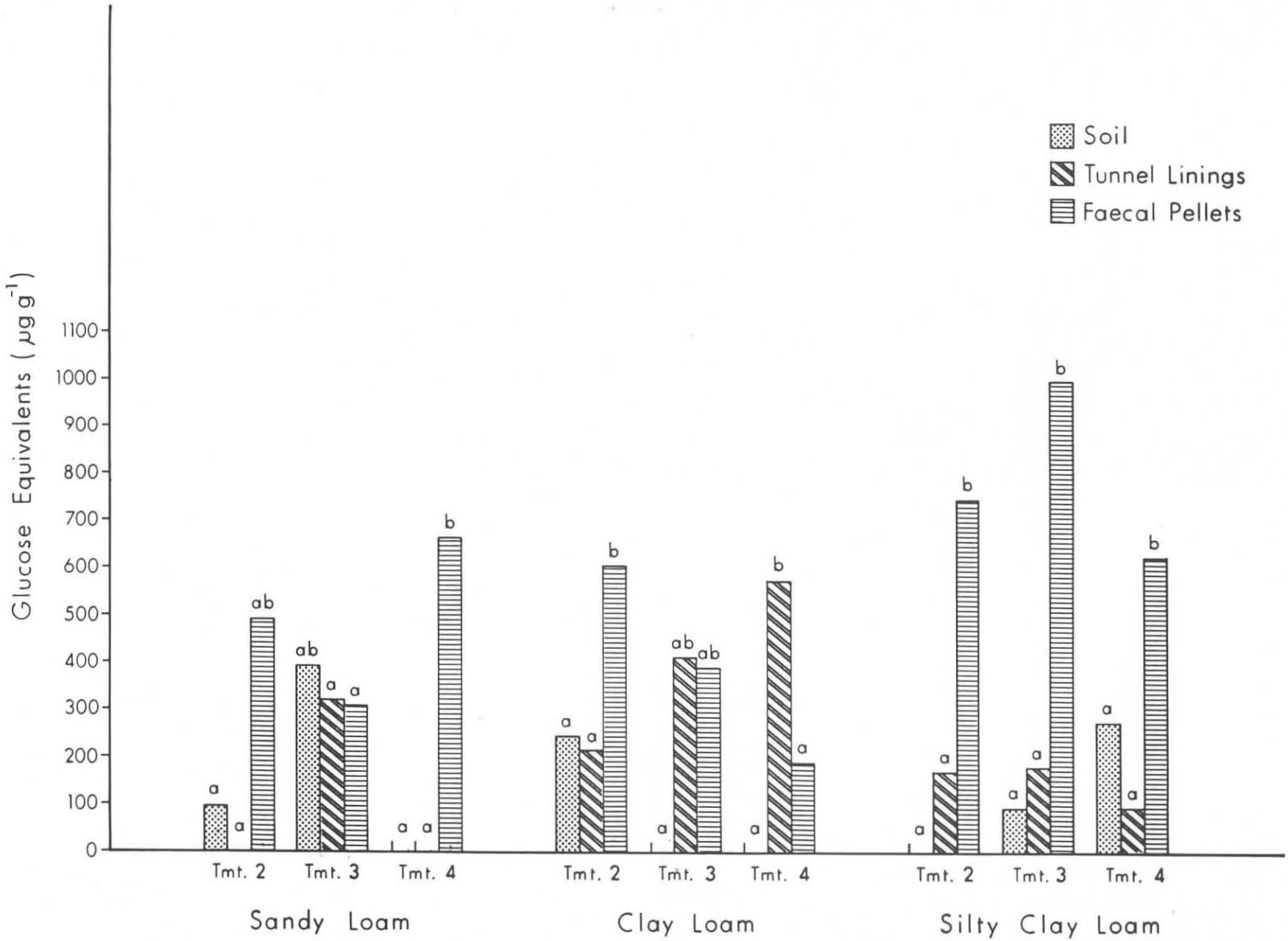

Fig. 7. Distribution of clay-bound neutral sugars (μg glucose eq g^{-1} soil) between treatments, soil textures and parts (a—b significantly different, within textures, $P \leq 0.05$).

material is humified and characterized by more small and less large phytogranic units than are present in Zone I of Treatment 3. The porphyric fabric characteristic of Zone I in Treatment 3 of the SL soils is not present in this treatment. Rather a mixed separated fabric (metafragmoidic matrichlamydic-matriplectic) with no porphyric component and less organic plasma occurs. In the SiCL soil a mullgranic fabric characterized by numerous discrete faecal pellets occurs in Zone I on the soil surface (Fig. 3d). This is immediately underlain by Zone II which is similar to Zone I in Treatment 2. A fused soil fabric developed to a greater extent in Zone I in the CL soil of this treatment than in any other treatment in the study (Fig. 2d). Zone III, common to all three soils, occurs in the lower most portion of the section. The fabric is similar to Zone II of Treatment 2 except that the porphyric component of the fabrics increases in dominance and phytogranic units are present. A decrease in metavughs and channels relative to Zone II of Treatment 2 occurs in the SiCL and CL soils.

3.2. Neutral sugars and uronic acids

No uronic acids were detected during the analyses of the samples. Statistically significant differences in the concentration of neutral sugars were found between parts (unaltered soil, tunnel linings, faecal pellets) and between components (free, clay-bound, residual neutral sugars). In some cases differences in neutral sugar concentrations of the aforementioned occurred as a result of soil texture or species of earthworm as well as an interaction of the two.

No statistically significant differences in the concentration of neutral sugars were found between the texture classes in Treatment 5. All parent materials had consistently low inherent levels of neutral sugars. In general the neutral sugar concentration in the unaltered soil material from Treatment 2, 3 and 4 were not statistically different from the controls making further comparisons at the parts and interaction levels valid.

Data for neutral sugar concentrations in the free and residual components showing the interaction of soil type with parts are shown in Figure 6. No significant differences resulted from a further interaction with species of earthworm. Regardless of soil texture or species of earthworm, free neutral sugar concentrations in the faecal material are always significantly higher than concentrations in the tunnel linings or unaltered soil. Concentrations in the tunnel linings and unaltered soil are always low and not significantly different. The residual component exhibits trends similar to those in the free component except concentrations of neutral sugars in the tunnel linings are significantly higher than in the unaltered soil for two of three soil types.

Significant differences in the concentrations of neutral sugars in the clay-bound component resulted as an interaction of soil type with part as well as species of earthworm (Fig. 7). In the SiCL soil the concentration of clay-bound neutral sugars in all treatments is significantly higher in the faecal material than the unaltered soil and tunnel linings in which concentrations are low and not significantly different. In the CL soil the concentration of clay-bound neutral sugars is significantly higher in the faecal pellets than the unaltered soil and tunnel linings only in Treatment 2, while in the SL soil this is observed only in Treatment 4.

3.3. X-ray Diffractometry

X-ray patterns of faecal pellet samples belonging to *O. tyrtaeum*/*A. turgida* from soils and *L. terrestris* faeces from the SiCL soil have a sharp 0.995 nm peak similar to that of the controls, both with and without treatment with H_2O_2. Patterns for clay separates of faeces belonging to *L. terrestris* from the SL and CL soils were identical to the controls following oxidation of the organic matter. Prior to oxidation a marked broadening of the 0.995 nm peak in the 1.3—0.995 nm region was observed.

4. Discussion

Results from the micromorphological studies demonstrate that ecologically distinct groups of earthworms can interact with different soils to produce a wide range in fabric types.

In soils where *L. terrestris* was active grass was completely removed from the soil surface and phytogranic units are present throughout the matrix material. These data suggest *L. terrestris* plays a primary role in structural development by initiating contact between organic and inorganic constituents. High concentrations of humified plasma binding inorganic components together in Zone I, and planar voids separating Zone I and II suggest this species also produces or enhances the production of organic constituents which firmly bind soil components together. Binding of soil constituents by *L. terrestris* resulted in fusion of the soil matrix in the SL and CL textured soils but a weakly expressed granular structure in the SiCL soil. Although alterations to soil fabrics by *L. terrestris* are profound they are localized as linings in the single permanent channel and as deposits on the soil surface. The fabric in Zone II, which constitutes the majority of the soil volume, remained relatively unaltered from that of the control.

Conversely *O. tyrtaeum/A. turgida* were active throughout the soil volume as observed in the construction of many ephemeral channels. Zone II is characterized by the presence of aggrotubules, metavughs and inclusions of material from Zone I. This reflects widespread earthworm activity that leads to homogenization of the soil fabric. Unlike *L. terrestris*, these earthworms had little contact with the surface litter which accumulated in a manner similar to the control. The low intensity of organic plasma development and absence of phytogranic units in the matrix is also indicative of the lack of contact with the litter layer. Behavioral characteristics of *O. tyrtaeum/A. turgida* strongly parallel those of *Allolobophora chlorotica* and *A. rosea* which BAL (1982) referred to as geophages. It is suggested that *O. tyrtaeum/Aporrectodea turgida* also be considered geophages who play a secondary role in structural development by contributing to organic plasma concentrations and by homogenizing the soil fabric.

Where both ecological groups of earthworms co-existed a synergistic effect upon structural development occurred. Processes initiated by *L. terrestris* were enhanced by the geophages. The withdrawal of litter from the surface into the soil by *L. terrestris* increased the availability of organic matter to the geophages. The geophages ingested and transported into the bulk of the soil, the new source of organic matter as well as material already modified by *L. terrestris*. Phytogranic units and porphyric fabric types, which occurred only in localized areas where *L. terrestris* was active alone, are present through the soil where the geophages were present also. The combined activities of the two ecological groups resulted in granic fabric types in the SL and SiCL soils and a strongly expressed fusion of the matrix in the CL soil.

Descriptions of plasma fabrics indicate that all the species of earthworms studied are effective in increasing the degree of orientation of clay domains. Unistrial and omnisepic plasma fabrics are common in the faecal material but not the control soils. In the past, development of these plasma fabrics has been attributed to physical forces such as wetting and drying (BREWER 1976). Although similar forces are likely involved when earthworms produce these fabrics data presented here provides evidence that a biological vector can be responsible for the forces.

Data from the chemical analyses strongly support the concept that earthworms increase stabilization of aggregates through enhancement of the concentration of clay-bound neutral sugars in their faeces. Where granular fabric types occurred [Treatments 2—4 (SiCL); Treatment 2 (CL); Treatment 4 (SL)] the concentrations of clay-bound neutral sugars in the faecal material are significantly higher than in the others parts. Where fusion of the matrix occurred [Treatment 3 (SL); Treatments 3—4 (CL)] concentrations of clay-bound neutral sugars in the faecal material are low. Although the data indicate that a favourable, granular structure is associated with high concentrations of clay-bound neutral sugars no conclusive data were collected to indicate why, in some cases, fusion of the soil matrix occurred. Results from x-ray diffractometry suggest the possibility that some other organic substance binds with clay to produce the fused structure. The expansion of the 0.995 nm peak occurred only in samples where a fused structure was observed in the thin sections and where clay-bound neutral sugar concentrations in the faecal material were low. AGAR-

WAL *et al.* (1958) attributed the fusion of soil with a CL texture to excretion of some colorless waxy fluid from the nymphridia of earthworms and PIERCE (1981) concluded that body secretions of earthworms played an important role in binding sand into stable aggregates. Possibly mucopolysaccharides, which are secreted to lubricate the gut (ARTHUR 1965) contributed to the development of the fused structure observed in the SL and CL soils. The high proportion of sand in these soils may aggravate the secretion of binding substances by earthworms. The fusion may be most strongly expressed in the CL soil since a high proportion of clays are also present to bind with secretions from the earthworms.

5. Acknowledgements

The authors acknowledge the Natural Science and Engineering Council for their financial support of this research and MICHAEL ABLEY for preparation of the thin sections.

6. References

AGARWAL, G., K RAO & L. NEGI, 1958. Influence of certain species of earthworms on the structure of some hill soils. Curr. Sci. **27** (6), 195—230.

ANDERSON, D., E. PAUL & R. ST. ARNAUD, 1974. Extraction and characterization of humus with reference to clay-associated humus. Can. J. Soil Sci. **54**, 317—323.

ARTHUR, D., 1965. Form and function in the interpretation of feeding in lumbricid earthworms. Viewpoint in Biology IV, pp. 204—251.

BABEL, U., 1975. Distribution of dropping fabrics in central European humus forms. In: VANĚK, J. (ed.), Soil Zoology. Academia, Czechoslovakia, pp. 85—94.

BAL, L., 1982. Zoological ripening of soils. Centre for Agricultural Publ. and Documents. Wageningen, 365 pp.

BITTER, T., & H. MUIR, 1962. A modified uronic acid and carbazole reaction. Anal. Biochem. **4**, 330—334.

BREWER, R., 1976. Fabric and mineral analysis of soils. 2nd printing. Robert E. Krieger Publ. Col., Huntington, New York.

— & S. PAWLUK, 1975. Investigations of some soils developed in hummocks of the Canadian Sub-Arctic and Southern-Arctic regions. 1. Morphology and Micromorphology. Can. J. Soil Sci. **55**, 301—319.

BUNTLEY, G., & R. PAPENDICK, 1960. Wormworked soils of eastern South Dakota, their morphology and classification. Soil Sci. Soc. Am. Proc. **24**, 128—132.

DORMAAR, J., & D. LYNCH, 1962. Ammendments to the determination of uronic acids in soils with carbazole. Soil Sci. Soc. Am. Proc. **26**, 251—254.

DOUTRE, D., G. HAY, A. HOOD & G. VANLOON, 1978. Spectrophotometric methods to determine-carbohydrates in soils. Soil Biol. Biochem. **10**, 457—462.

DUBOIS, M., K. GILLES, J. HAMILTON, P. REBERS & F. SMITH, 1956. Colorometric method for determination of sugars and related substances. Anal. Chem. **28** (3), 350—356.

GREENLAND, D., & J. OADES, 1975. Saccharides. In: GIESEKING, J. (ed.), Soil components: Organic components. Springer Verlag, New York. Inc. U.S.A.

KÜHNELT, W., 1958. Zoogenous crumb formation in undisturbed soil. Dtsch. Akad. Landw. Bln. Tagungsbericht No. **13**, 193—199.

LANGMAID, K., 1964. Some effects of earthworm invasion in virgin podzols. Can. J. Soil Sci. **44**, 34—37.

MCGRATH, D., 1971. The determination of uronic acid (and sugar) in soil. Geoderma **5**, 261—269.

NIELSON, G., & F. HOLE, 1964. Earthworms and the development of coprogenous A_1 horizons in forest soils of Wisconsin. Soil Sci. Soc. Am. Proc. **28**, 426—430.

PEREL, T., 1977. Differences in lumbricid organization connected with ecological properties. In: LOHM, U., & T. PERSSON (eds.), Ecological Bulletin No. **25**, pp. 56—63.

PIEARCE, T. G., 1981. Losses of surface fluids from lubricid earthworms. Pedobiologia **21**, 417—426.

THOMAS, R., & D. LYNCH, 1961. A method for the quantitative estimation of pentoses in soil. Soil Science **91**, 312—316.

THORP, J., 1949. Effects of certain animals that live in soils. Sci. Monthly **68**, 190—191.

Address of the authors: CINDY SHAW and Dr. S. PAWLUK, Department of Soil Science, University of Alberta, Edmonton, Alberta, Canada T6G 2E3.

Synopsis: *Original scientific paper*
Shaw, C., & S. Pawluk, 1986. The development of soil structure by *Octolasion tyrtaeum*, *Aporrectodea turgida* and *Lumbricus terrestris* in parent materials belonging to different textural classes. Pedobiologia **29**, 327—339.

A microcosm study was set up to determine if the development of soil structure by earthworms varied depending on the species, and type of soil involved, and to examine potential mechanisms for stabilization of soil structure by earthworms. The type of soil fabric produced by *O. tyrtaeum*/*A. turgida* and/or *L. terrestris* varied with the type of soil in which they were active. A granular, mull structure was produced by all species in the SiCL soil. This structural development was most strongly expressed where both ecological groups of earthworms co-existed. Granular structure was also produced where *O. tyrtaeum*/*A. turgida* were active alone in the CL soil and where both ecological groups co-existed in the SL soil. The development of a favourable structure in all of these cases was associated with high concentrations of clay-bound neutral sugars in the earthworms' faeces. Fused structure developed where *L. terrestris* was active alone in the SL and CL soils and was greatest where both ecological groups co-existed in the CL soil. No conclusive data were collected to indicate why the fused structure formed. Although, in these cases the concentrations of clay-bound neutral sugars in the faecal material were low, x-ray diffractometry indicated that some other organic substance may be involved in binding with clays. Possibly secretion of mucopolysaccharides from the bodies of the earthworms, aggravated by the presence of a high proportion of sand in the soil, contributed to the development of the fused structure.

In summary, this study showed that earthworms can positively or negatively influence soil structure depending on the species of earthworms and/or the nature of the soil. In this study favourable soil structure that resulted from earthworm activity was associated with a high concentration of neutral sugars in the faecal material.

Key words: Earthworms, soil structure, soil texture, neutral sugars.